

EXTRACTION OF $R = \frac{\sigma_L}{\sigma_T}$ FROM CCFR ν_μ -Fe and $\bar{\nu}_\mu$ -Fe DIFFERENTIAL CROSS SECTIONS

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We report on the extraction of $R = \frac{\sigma_L}{\sigma_T}$ from CCFR ν_μ -Fe and $\bar{\nu}_\mu$ -Fe differential cross sections. R as measured in ν_μ scattering is in agreement with R as measured in muon and electron scattering. All data on R for $Q^2 > 1 \text{ GeV}^2$ are in agreement with a NNLO QCD calculation which uses NNLO PDFs and includes target mass effects. We report on the first measurements of R in the low x and $Q^2 < 1 \text{ GeV}^2$ region (where an anomalous large rise in R for nuclear targets has been observed by the HERMES collaboration).— UR-1635, Proceedings of DIS2001, Bologna April 2001

The ratio of longitudinal and transverse structure function, $R (=F_L/2xF_1)$ in deep inelastic lepton-nucleon scattering experiments is a sensitive test of the quark parton model of the nucleon. Recently, there has been a renewed interest in R at small values of x and Q^2 , because of the large anomalous nuclear effect that has been reported by the HERMES experiment¹. A large value of R in nuclear targets could be interpreted as evidence for non spin 1/2 constituents, such as ρ mesons in nuclei². Previous measurements of R in muon and electron scattering ($R^{\mu/e}$) are well described by the $R_{world}^{\mu/e}$ ³ QCD inspired empirical fit. The $R_{world}^{\mu/e}$ fit is also in good agreement with recent NMC muon data for R at low x , and with theoretical predictions⁴ $R_{NNLO+TM}^{\mu/e}$ (a Next

to Next to Leading (NNLO) QCD calculation using NLO Parton Distribution Functions (PDFs), and including target mass effects). Very recently the NNLO calculations for F_L and F_2 have been updated⁶ to include estimates of the contribution from NNLO PDFs. The quantity $R_{NNLOpdfs+TM}^{\mu/e}$ is extracted by adding target mass effects to these calculations of F_L . For $x > 0.1$ it is expected that R^ν should be the same as $R^{\mu/e}$. However, for $x < 0.1$ and low Q^2 (in leading order), R^ν is expected to be larger than $R^{\mu/e}$ because of the production of massive charm quarks in the final state. We calculate a correction to $R_{world}^{\mu/e}$ for this difference using a leading order slow rescaling model with a charm mass, $m_c (= 1.3 \text{ GeV})$ and obtain an effective R_{world} for ν_μ scattering (R_{eff}^ν). Here, we report on an extraction of R in neutrino scattering (R^ν), extending to low x and Q^2 , and compare to $R^{\mu/e}$ data and to predictions from R_{eff}^ν , $R_{world}^{\mu/e}$, and $R_{NNLOpdfs+TM}^{\mu/e}$.

The sum of ν_μ and $\bar{\nu}_\mu$ differential cross sections for charged current interactions on isoscalar target is related to the structure functions as follows:

$$F(\epsilon) \equiv \left[\frac{d^2\sigma^\nu}{dx dy} + \frac{d^2\sigma^{\bar{\nu}}}{dx dy} \right] \frac{(1-\epsilon)\pi}{y^2 G_F^2 M E} \\ = 2xF_1[1 + \epsilon R] + \frac{y(1-y/2)}{1+(1-y)^2} \Delta x F_3. \quad (1)$$

Here G_F is the weak Fermi coupling constant, M is the nucleon mass, E_ν is the incident energy, the scaling variable $y = E_h/E_\nu$ is the fractional energy transferred to the hadronic vertex, E_h is the final state hadronic energy, and $\epsilon \simeq 2(1-y)/(1+(1-y)^2)$ is the polarization of virtual W boson. The structure function $2xF_1$ is expressed in terms of F_2 by $2xF_1(x, Q^2) = F_2(x, Q^2) \times \frac{1+4M^2x^2/Q^2}{1+R(x, Q^2)}$, where Q^2 is the square of the four-momentum transfer to the nucleon, $x = Q^2/2ME_h$ (the Bjorken scaling variable) is the fractional momentum carried by the struck quark, and $R = \frac{\sigma_L}{\sigma_T} = \frac{F_L}{2xF_1}$.

Values of R (or equivalently F_L) and $2xF_1$ are extracted from the sums of the corrected ν_μ -Fe and $\bar{\nu}_\mu$ -Fe differential cross sections at different energy bins according to Eq. (1). An extraction of R using Eq. (1) requires a knowledge of $\Delta x F_3$ term, which in leading order $\simeq 4x(s-c)$. We obtain $\Delta x F_3$ from theoretical predictions⁵ for massive charm production using the TR-VFS NLO calculation with the extended MRST99 and the suggested scale $\mu = Q$. This prediction is used as input to Eq. (1) in the extraction of R^ν . This model yields $\Delta x F_3$ values similar to the NLO ACOT Variable Flavor Scheme (implemented with CTEQ4HQ and the recent ACOT suggested scale $\mu = m_c$ for $Q < m_c$, and $\mu^2 = m_c^2 + 0.5Q^2(1 - m_c^2/Q^2)^n$ for $Q > m_c$ with $n = 2$). A discussion of the various theoretical schemes for massive charm production is given in a previous communication⁵. Because of a positive correlation between R and $\Delta x F_3$, the uncertainty of $\Delta x F_3$ play as a major systematic error at low

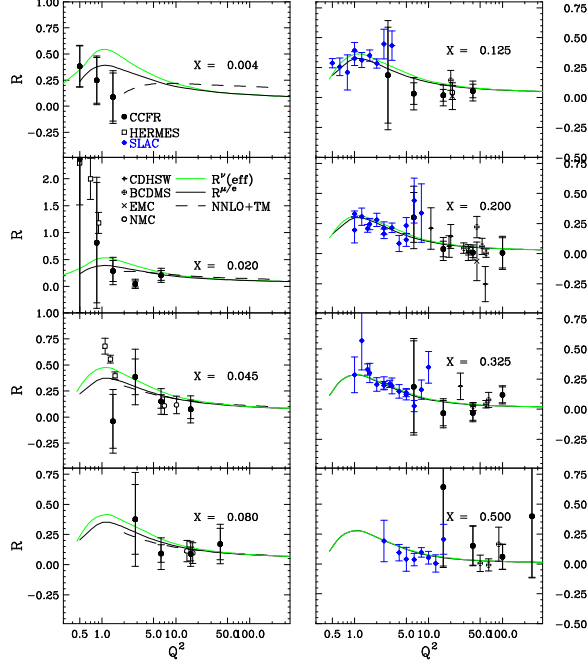


Figure 1: CCFR measurements of R^ν as a function of Q^2 for fixed x , compared with electron and muon data, with the $R_{world}^{\mu/e}$ and R_{eff}^ν ($m_c = 1.3$) fits, and with the $R_{NNLOpdfs+TM}^{\mu/e}$ QCD calculation including NNLO PDFs (dashed line). The inner errors include both statistical and experimental systematic errors added in quadrature, and the outer errors include the additional $\Delta x F_3$ model errors (added linearly). Also shown are the HERMES results for R_{N14}^e at small x and Q^2 .

x region. However, for $x > 0.1$, the $\Delta x F_3$ term is small, and the extracted values of R^ν are not sensitive to $\Delta x F_3$. For a systematic error on the assumed level of $\Delta x F_3$, we vary strange sea and charm sea by $\pm 50\%$ ($\Delta x F_3$ is directly sensitive to the strange sea minus charm sea). Note that the extracted value of R is larger for a larger input $\Delta x F_3$ (i.e. a larger strange sea).

The extracted values of R^ν are shown in Fig. 1 for fixed x versus Q^2 . The inner errors include both statistical and experimental systematic errors added in quadrature, and the outer errors include the additional $\Delta x F_3$ model errors (added linearly).

At the very lowest Q^2 values, the model error is reduced because all models for $\Delta x F_3$ approach zero around $Q^2 = 0.4$. This is because the strange quark

distribution is expected to approach zero for Q values close to twice the mass of the strange quark. In addition, the very low Q^2 region is below charm production threshold. Note that the very low Q^2 and low x region is of interest because it is where HERMES reports¹ an anomalous increase in R^e for nuclear targets.

The CCFR R^ν values are in agreement with measurements of $R^{\mu/e}$, and also in agreement with both the $R_{world}^{\mu/e}$ and R_{eff}^ν fits. At low x , there are indications that the data may be lower than these two model predictions. New QCD calculation⁶ of F_L and F_2 including both the NNLO terms and estimates of NNLO PDFs are used to determine $R_{NNLOpdfs+TM}^{\mu/e}$, by including target mass effects. These are shown as dashed lines in Fig. 1. There are large uncertainties in F_L from the NNLO gluon distribution at low x for $Q^2 < 5 \text{ GeV}^2$. Specifically, for $Q^2 = 2 \text{ GeV}^2$ and $0.001 < x < 0.01$ the NNLO calculation with NNLO PDFs results in a dip in F_L with F_L approaching zero. It is interesting that there is also a dip in our measured values of R for $x=0.019$ and $Q^2 = 3 \text{ GeV}^2$. However, for $Q^2 < 2 \text{ GeV}^2$ and $0.001 < x < 0.01$ the NNLO calculation with NNLO PDFs also yields an unphysical negative value for F_L , which implies large uncertainties in the calculation. Another recent QCD calculation within a $\ln(1/x)$ resummation framework (with resummed PDFs) also predicts⁷ that R at small x and low Q^2 is lower than $R_{world}^{\mu/e}$.

Also shown are the HERMES electron scattering results in nitrogen. The HERMES data¹ for R are extracted from their ratios for R_{N14}/R_{1998} by multiplying by the values from the R_{1998} fit. The CCFR data do not clearly show a large anomalous increase at very low Q^2 and low x . It is expected that any nuclear effect in R would be enhanced in the CCFR iron target with respect to the nitrogen target in HERMES. However, depending on the origin, the effects in electron versus ν_μ charged current scattering could be different.

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